



Optimizing Astronaut Performance For Long Duration Spaceflight



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Physiological Changes Associated with Space Flight

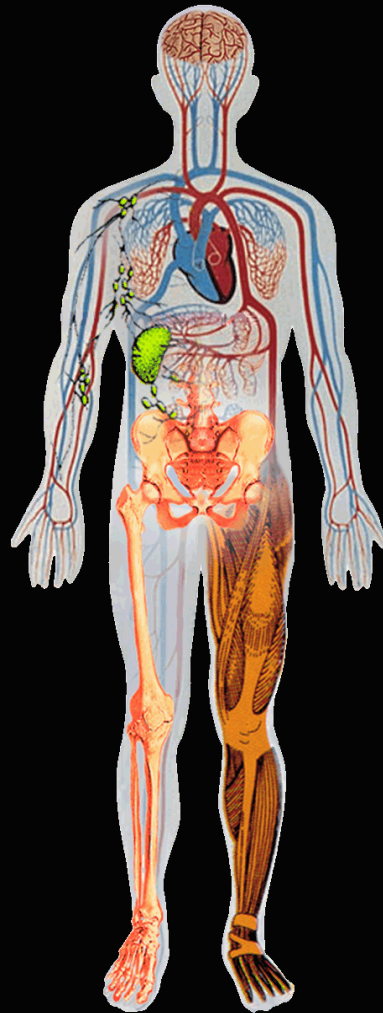


Bone

- ↓ Bone mineral content
- ↓ Bone mineral density
- ↑ Urinary calcium
- ↑ Renal stone risk

Skeletal Muscle

- ↓ Skeletal muscle mass
- ↓ Skeletal muscle strength
- ↓ Skeletal muscle endurance
- ↓ Skeletal muscle capillary density



Neurosensory

- ↓ Vestibular disturbances
- ↓ Sensorimotor function
- ↓ Postural & locomotor stability

Cardiovascular

- ↓ Fluid volume
- ↓ Orthostatic tolerance
- ↓ Aerobic capacity
- ↓ Cardiac function

ISS Exercise



- 2.5 hrs/day, 6 days/wk
- Resistance exercise
 - Historically high reps low loads
 - iRED now ARED
- Aerobic exercise
 - 30 min continuous at $\sim 70\%$ HRmax
 - Some moderate intensity intervals
 - TVIS & CEVIS



Prescription

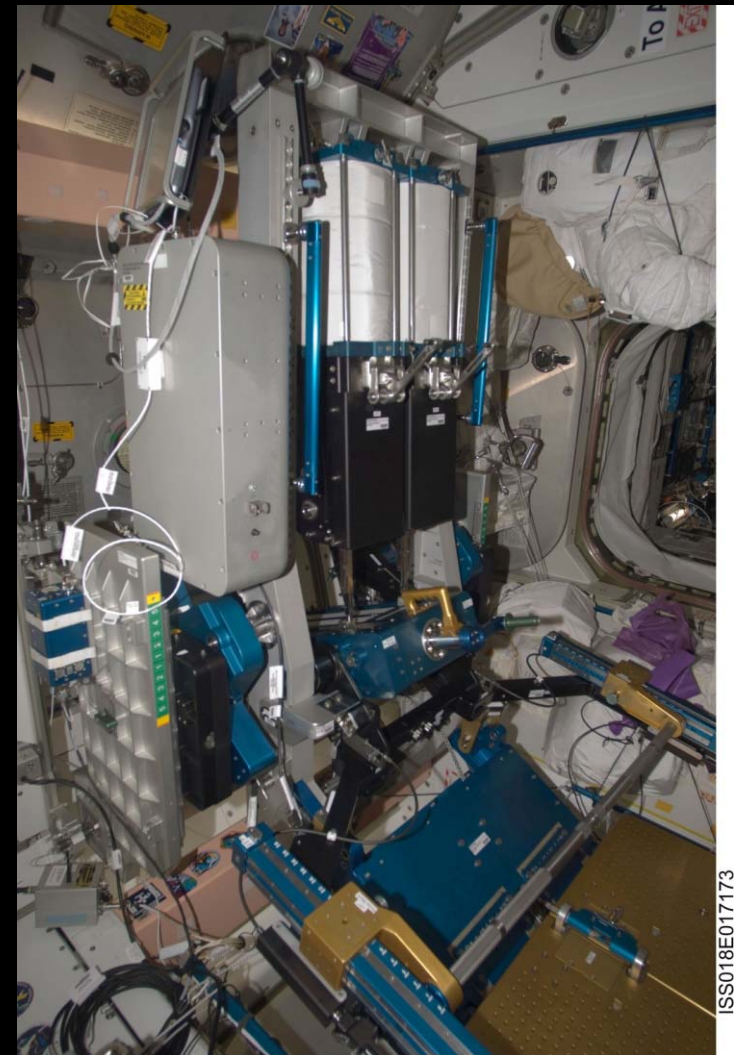


- **Basic Changes to the Typical ExRx**
 - Higher intensity, less exercise time
 - 3 days/week instead of 6 days/week resistance exercise
 - 3-12 RM periodized
 - Aerobic exercise every day
 - Also periodized
 - 30 min continuous on resistance days
 - High intensity intervals on alternate days (15-35 min)



ISS Hardware - ARED

- More exercises (29 different ones)
- Improved loading
 - Ecc-Con Ratio ~90%
 - Simulated inertia (free weight)
 - 600 lbs
- Instrumented for data acquisition
 - Sets
 - Reps
 - Ground reaction forces
 - Load at the bar





ARED



Exercise Equipment – T2



- **T2 treadmill**
 - New loading system in development
 - Instrumented
 - Ground reaction forces
 - Impact loads
 - Improved speed



T2



Bed Rest Analogue

- 6° head-down tilt bed rest an accepted analogue for studying the effects of spaceflight on cardiovascular, muscle, and bone physiology.
- Control and “countermeasure” subjects
- Subjects adhere to a set of standard conditions (i.e. diet, sleep, hygiene).



Exercise Training in Bed Rest



Exercise Training in Bed Rest



Testing Technologies



S119E010316



Muscle Assessments

Whole Muscle → Cellular Level

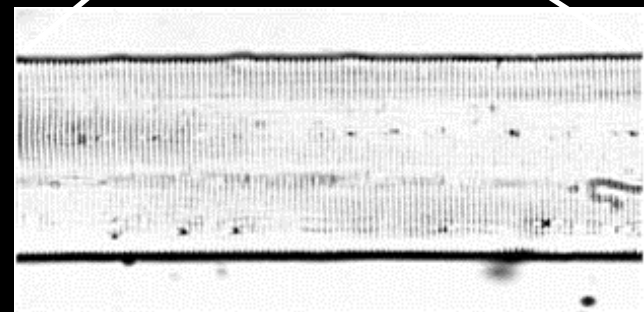
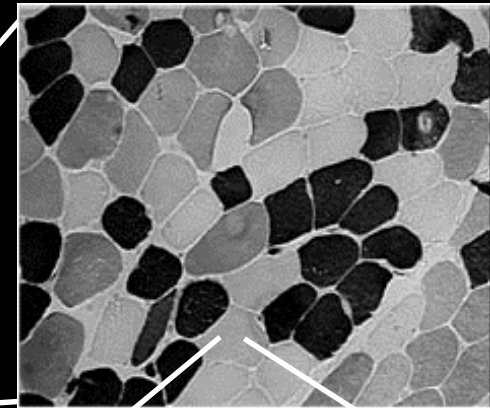


Exercise on the ISS



MRI Scan
Whole Muscle Size
(15% loss on ISS*)

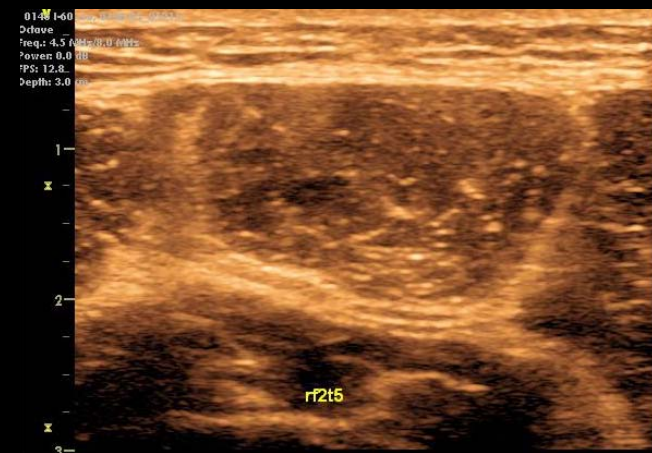
Muscle Biopsy Sample



One Muscle Fiber

* *J Appl Physiol* 106: 1159-68, 2009 and *ASEM* 81: 91-102, 2010

Muscle Assessment

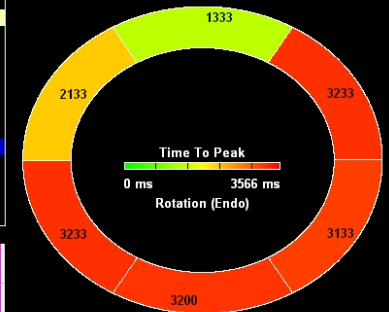
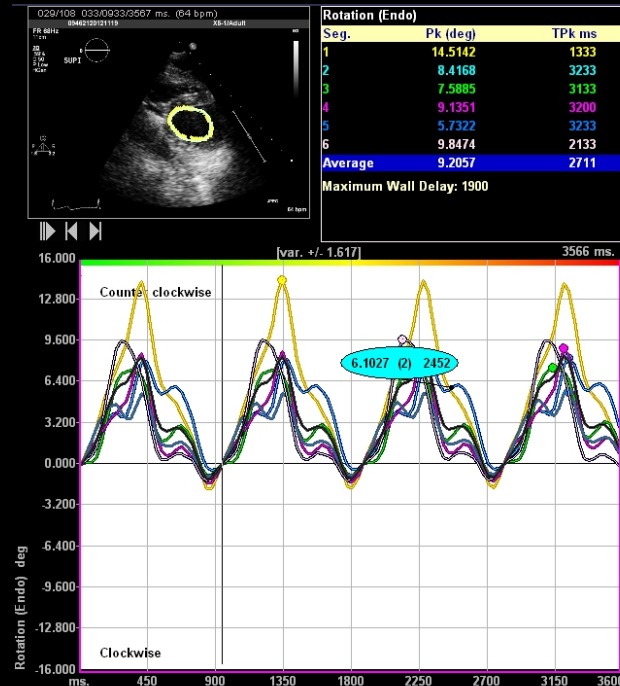


QCT After Flight: Greater percentage loss vBMD in trabecular bone compartment (n=16 ISS)



LeBlanc, J M Neuron Interact, 2000;
Lang, J Bone Miner Res, 2004;
Vico, The Lancet 2000

Cardiovascular Fitness/Cardiac Function





Cutting Edge Training and Testing Technologies: Optimizing Astronaut Performance For Long Duration Spaceflight



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